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Process and Skill: Analyzing Dynamic Structures of Growth

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Abstract. People create complex behaviors from the actions of brain, body, and world working together dynamically in coordination. They construct their own development and learning along pathways that can be observed, revealing laws that explain the construction of complex actions and resonate with Whitehead's descriptions of the processes underlying reality. Dynamic skill theory provides a set of tools to empirically analyze how people build their specific activities, using simpler structures to construct more complex ones – not just in the young but throughout the life course, not just over months and years but in the moment. Each person acts in a variable range along his or her learning pathways, not with a fixed skill or understanding. Whitehead's concepts of prehension and concrescence resonate particularly closely with the processes in human action. A dialog between cognitive science and process philosophy can lead to new understanding of how people participate in their world and with each other, and how they grow and learn.

1. Introduction

Imagine we are looking in on an experiment in progress. The room is large, with a few small tables, chairs, and boxes here and there; there is a video and sound recorder at one end, tended by a silent researcher, and in the middle of the room two graduate students are interacting with a miniature robotic creature called a wuggle (an early version of a Lego robot before commercial availability). The wuggle moves around the room on its own, responding to light, sound, or touch. The task is to figure out "what's going on" with the wuggle. The students build up their knowledge of the robot by trying out a number of actions: This action makes it turn left; this one makes it go forward; and – oh, if you clap your hands, it reverses direction! It is a fun experience for the students as they talk with each other about what they think the wuggle does and how it operates. The wuggle has a few surprises for them, so there is plenty of challenge in figuring it out. They begin with primitive, confused actions and ideas about the wuggle, and they gradually build up a more stable understanding over many, repeated efforts and with numerous temporary advances in understanding that fall back again to primitive actions. Now that you have the experiment in your mind's eye, what do you think it can show about learning and knowledge?

Well conducted developmental research tries to catch the important characteristics of learning and knowing through analyzing the changes of some specific behavior over time. In this experiment, we are trying to look in on the mind itself as it constructs understanding and knowledge (Fischer & Granott 1995; Granott 2002). The language and behavior of the students as they try different strategies provide the data about the details of thought in action. We can observe an idea being built up, and then when it does not seem to fit the facts of the wuggle's movements, the students break it back down to levels they are more certain of – a pattern that can be plotted out in a growth curve showing the movement of mind in the construction of knowledge, as illustrated in Figure 1. The y-axis indicates the hierarchical complexity of an activity, an important concept that will be elaborated later (Fischer 2007, in press).

People build up a way of acting on and understanding the wuggle, but it is unstable, and their actions frequently fall back to a lower level, until they try again and once more build up a more complex action/understanding. Gradually over time the repeated rebuilding leads to construction of "knowledge", a relatively stable pattern of activity that people can evoke with the wuggle. A skill is built and rebuilt many times so that it can become a general scheme for knowing.

The analysis of learning in action over relatively brief time periods is called *microdevelopment* or microgenesis, the short-term development of an activity or understanding. It is designed to capture the small, moment-by-moment changes in behavior where a person actually constructs skill and understanding. We will look more closely at this research later, but for now it highlights two important points: First is the idea that human development and change builds from elemental steps that can be observed and studied, leading to the discovery of laws that illuminate how we human beings become the complex beings we are. The second point follows from the first: Using the right tools, both conceptual and material, is essential to generating useful data and to interpreting it to tell a clear story about how people develop the activities. Skill Theory supplies such a tool set.

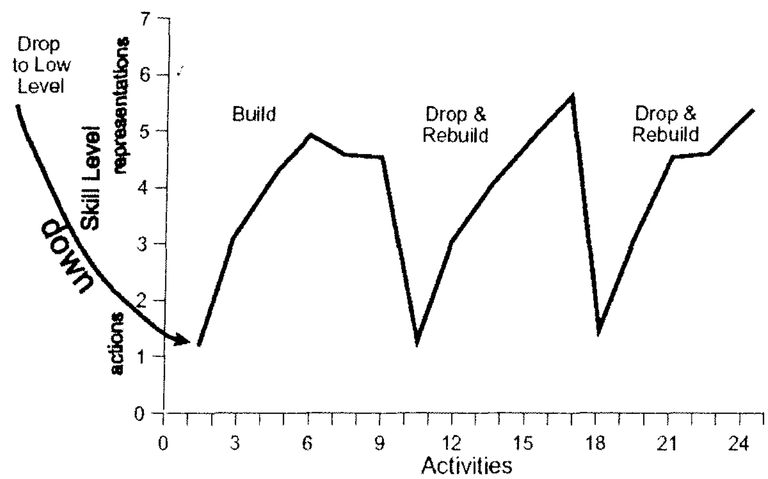

Figure 1. Building new knowledge through repeated construction
Facing a new task, people build transient knowledge, which easily falls apart. They rebuild it multiple times to eventually create more stable knowledge. The y-axis denotes level of skill, based on the standard skill scale (Fischer & Bidell, 2006).

Skill Theory provides a conceptual structure for thinking about the processes involved in development and learning, with a set of tools that afford ways of designing methodologies for observation and intervention and analyzing their results (Fischer 1980; Fischer & Bidell 2006). After describing the principles of the theory, we will examine several research findings from work with children, adolescents, and adults. These examples will show how complex behaviors arise out of early coordinations of brain, body, and world, and how such developments in all behavior depend on specific processes of cognition and emotion that facilitate the usage of simpler structures in the construction of more advanced ones – not just in the young, but throughout the life course, not just over months and years but in the moment.

This view of human learning and development contrasts dramatically with the implicit model in behavioral science. For the implicit (assumed) model, a person is treated as primarily a brain, disembodied as if in a bucket and plugging into the world as needed to download information. Most people use this dominant metaphor for the human mind without knowing that they are using it, in the way that unconscious metaphors routinely underlie human acting and knowing, as George Lakoff (1987) has described. In Skill Theory, in contrast, people build knowledge in context in the moment, and with experience they can recreate certain kinds of activities and knowledge. They always construct it in the moment; they never simply possess it as a static object in the mind.

After the discussion of Skill Theory and its portrayal of human learning, feeling, and thinking, we will describe how developmental processes resonate with Whitehead's (1929/1978) descriptions of processes that underlie the structure of reality. It should come as no surprise that deeply human processes – psychological, behavioral, or physiological – share fundamental characteristics with the processes that generate worlds and their ways. But the details of those parallels have not been specified in any depth before – apart from general philosophical considerations foreseen by pioneers such as William James (1890/1950), who did not possess the tools to allow the depth of behavioral study possible today. We hope that the remarkable closeness of the process functions in Skill Theory and Whitehead's analysis can help open a constructive dialog between the fields of education, psychology, philosophy, and biology that may lead to fuller, deeper explanations of human behavior and its connections with other levels of existence analyzed by physics and chemistry. As Skill Theory, and developmental science in general, continue to add flesh and bones to an undertanding of Whiteheadian processes, we expect a growing connection between Whitehead's concepts and cognitive developmental science. At the very least, this dialog should provide new ways of thinking about how people participate in the world and with each other, and what possibilities may lie ahead. But now let's begin with the description of Skill Theory.

2. Skill Theory

In 1980 Fischer first presented the Skill Theory of development and learning with a paper entitled "A Theory of Cognitive Development: The Control and Construction of Hierarchies of Skills". Research and collaboration over the years have led to expansion and elaboration of the theory, including greater specification of the basic principles and more explicit connections with brain functioning, emotional development, and short-term learning (Fischer & Bidell 2006; Fischer & Yan 2002). The theory belongs to a class of ideas about human behavior that can be called neo-Piagetian, constructivist, and dynamic.

Skill Theory builds on the seminal work of Jean Piaget (1983), J. M. Baldwin (1894), Sigmund Freud (1917), Harry Stack Sullivan (1953), and Lev Vygotsky (1978). Piaget established many of the key concepts with his careful observation of how children build relatively stable psychological structures by moving through a series of stages of knowledge. Piaget considered these stages to be universal logical structures common to all cultures and applicable across all domains and in all children. His framework has proven to be fundamentally wrong, because activity and knowledge vary greatly across moments, people, and cultures and because logic is not the basis of understanding.

At the same time, the focus on explaining thought and learning by analyzing its development has provided keen observations that show a central principle that fits well with Whitehead's focus on process as the foundation of reality: Children's (and adults') activities show much more variability of diverse kinds than earlier theories predicted, highlighting the roles of dynamic processes in generating activity and knowledge. The concept of a singular forward direction of growth does not explain the great variability actually observed. Knowing activity moves up and down in complexity routinely with learning and context, as shown in Figure 1. People do not function with a single structure of skill but vary their skills widely as a function of support and context. The central organization of activity is not captured well by logical structures, because as Freud and Sullivan described, affective and illogical structures are pervasive in human behavior and people are routinely inconsistent. At the same time, research has shown substantial order in the variation.

One of the most important kinds of order is that for optimal performance, activity does indeed move through systematic levels of increasing complexity, forming a reliable scale for knowing that is far more differentiated than Piaget's broad stages and that can be rigorously pinned down empirically. In other words, in ontogenesis (long-term development) children do move through a long series of skill levels between birth and age 30 when they act under optimal (high support) contexts. This order is obscured when researchers and educators ignore the contributions of context, emotion, and culture to activity. By attending to these other factors, we have been able to find the order in the variation and systematically document the skill levels of both long-term development and microdevelopment.

In being constructivist, Skill Theory holds that people advance developmentally through actively engaging their minds and bodies with the world of people and things. Growth is an active construction, born out of earlier skills and issuing forth in new organizations of behavior. This construction happens with every instance of knowing, doing, feeling, and learning – in the moment as well as in the long term. Activities build on earlier activities, starting with the initial reflexes of infancy and moving to more complex activities called actions, representations, and eventually abstractions and principles. All activities and skills develop through interaction that tests and consolidates them, leading in turn to new skills that afford further testing, consolidation, and modification.

In Skill Theory, activity and development are dynamic in all the senses of the word: People act by adapting dynamically and in highly variable ways, they act based on the dynamics of emotions and unconscious processes, and their actions have the properties of nonlinear, dynamic systems, including mostly nonlinear patterns of change in activity, as we will show in describing research. The dynamic nature of these processes regulates the enormous variability of activity and development (Fischer & Bidell 2006; Fischer & Kennedy 1997; Siegler 1994). As researchers have devised methodologies to analyze the variability, they have discovered the strange and diverse shapes of pathways of learning and development – shapes that a new science of dynamic systems theory is just beginning to model. There are sudden transitions in growth. There is frequent return to lower ("earlier") organizational levels on the way to settling into a new relatively stable level. Environmental factors like the properties of a toy or the help of a teacher have critical influences that strongly affect the shape of growth. Explaining these diverse shapes requires the modeling tools of dynamic systems theory, which can make the variability "speak" and illuminate the processes of growth.

A final introductory concept in Skill Theory concerns the word "skill" itself – which has several important implications. First, there is the focus on a person's actions: A skill is a set of activities that someone performs in a characteristic manner. Second is the sense of an action performed on some feature of the world: A skill is a practiced manipulation of a specific object, which can be a tool, a word, or an idea, but the emphasis is on the capacity for dexterous engagement with a specific context or task. Third is the sense of a learned, well-practiced ability: Skill implies a dedicated building up of elements in systematic execution. New skills are acquired through effortful application of existing skills as well as through adapting newly encountered demands in coordination or thoughtful strategy to the overall performance. Fourth, skill carries the sense of being a recognizable accomplishment: It is held both by its possessor and by others as a specific mode of being that reflects committed resources of time, effort, ability, and dedication. That is, a skill has cachet in the sense of a living advantage that stands out, a mark of distinction. Finally, there is a key sense that the word "skill" does not obviously imply: Feeling pervades action. Emotion shapes how people act in every moment. Skill Theory is the description of how all these meanings of skill are manifest in development of action, thought, and feeling.

3. Principles of Skill Theory: Order within Variation

Skill Theory offers a dynamic view of development, requiring analysis of the complex relationships among body, person, and environment in activities (Fischer 1980; Fischer & Bidell 2006). The hierarchical structures and methods specified by Skill Theory offer researchers a toolkit for observing the emerging complexity of behavior as a conceptual instrument based on the ordered patterns of components interacting in the ecology of a given task. Fortunately the many complexities come together to form several broad principles that are conceptually straightforward and that help to make sense of the complexities and contextual specifics of actions, thoughts, and feelings.

3.1 The Web of Development and Learning

A person acts in the moment by coordinating behaviors in a situation or context to prehend some event or thing, knowing and feeling it. The wuggle task highlights this active process through microdevelopmental analysis of understanding, which is naturally unstable and under construction. With time and experience, people build activities that are more stable in the sense that they can be reconstituted with some reliability in a situation. Reliability in one situation does not extend easily across contexts, however: To generalize a skill to a new context, a person must rebuild it by trying it out again and again over long periods.

Skills naturally fit in specific domains (classes of closely related situations), within which they develop both ontogenetically and microdevelopmentally. Development moves along independent strands for distinct domains, forming a pattern very different from the ladder of stages that most people assume when conceiving of development. The web of development and learning provides a better metaphor than the ladder, with each strand representing learning and development in a distinct domain, as shown in Figure 2. Examples of domains can be subjects for learning in school, such as reading and mathematics; situations of common experience, such as playing with Lego robots versus building toy bridges; or affective states shaping behavior, such as positive versus negative emotions. Figure 2 shows a web with two primary domains, nice versus mean social interactions. In the middle of the web, some skill activities combine nice and mean; but most skills separate them as a result of the fundamental human bias to split positive and negative, good and bad, nice and mean (Fischer, Shaver & Carnochan 1990).

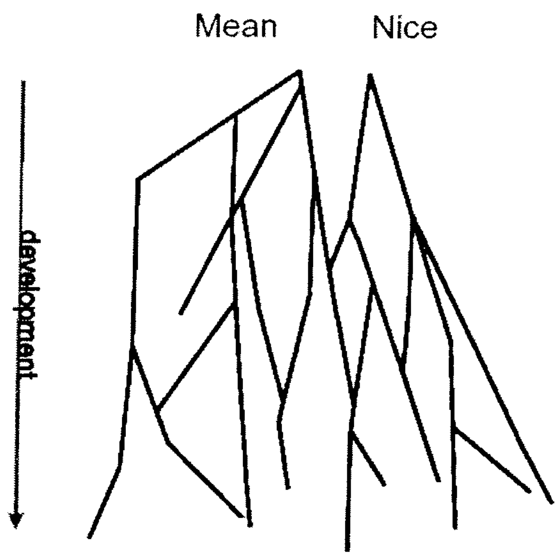

Figure 2. Web of development of mean and nice social interactions

People learn skills along specific strands or pathways in a web of development. The strands group into domains defined by context and emotion, such as mean versus nice social interactions. The domains remain mostly separate but sometimes connect through specific strands, as shown in the middle of the web.

3.2 Contextual Support: Optimal and Functional Levels

Besides situation and emotion, support within context powerfully determines a person's skill. People shift their activity sharply depending on the degree that a context supports a specific skill by priming key components. For example, 7-year-old children telling stories about nice and/or mean social interactions with peers showed highly consistent differences as a function of support: They consistently produced much less complex stories without specific contextual support than they did with it. Their performance moved up and down systematically as support came and went (Fischer, Bullock, Rotenberg & Raya 1993). Contextual support involved presenting a specific story or the gist of a story to remind a child of the main components of an appropriate performance, thus priming working memory. For a few minutes afterward, children produced a more complex story as shown in the higher levels of the graph in Figure 3 – called *optimal level*. But a few minutes later, the effect of the support dissipated: Without support they were asked to make up their own stories or tell the best stories that they could, and they produced much simpler stories, as shown in the lower levels of the graph, called *functional level*. Remarkably, the shift between optimal and functional levels occurred repeatedly: Each time that high contextual support was provided, children's stories increased sharply in complexity to their optimal level, but the high level lasted only for a few minutes unless the support was repeated. Without support, their stories dropped dramatically in complexity to their functional level.

This phenomenon demonstrates one of the most dramatic ways that skills involve continuous process: The context participates with the person in creating the activity. This process is highly general, occurring routinely every moment as people act, think, and fell in their daily lives. The process is not limited to children but characterizes adult activities as well, with high levels of understanding in a college course or a mechanics shop varying up and down with changes in the support provided in the context from moment to moment. Every one of us has experienced understanding something in a complex way when we read or heard a well structured, explicit explanation of it, only to have that complex understanding descend to a much lower level a short time later when the benefit of the support had dissipated (Fischer, Yan & Stewart 2003).

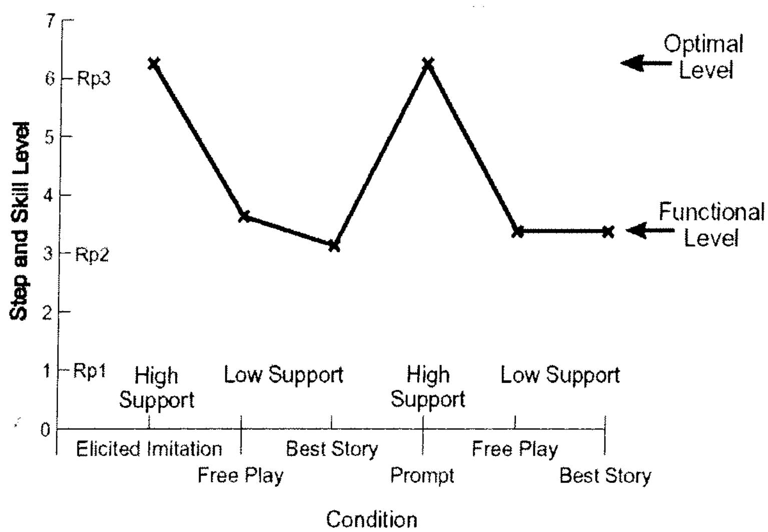

Figure 3. Variation in optimal and functional levels of knowledge as a function of contextual support

Children at age 7 produced complex stories under high support conditions and much simpler stories with low support (Fischer, Bullock, Rotenberg & Raya, 1993). These variations occur in a matter of minutes, as the effects of high support quickly dissipate. High support creates optimal-level action – the highest level that a person can do with support – while low support creates ordinary, functional-level action, the highest level with little or no support. High support conditions in this study included elicited imitation (an interviewer modeled a story to the child) and prompt (she stated the gist of the story). Low support conditions included free play (she provided no support but instead asked the child to make up stories of his own like the ones that he had heard from her before) and best story (she asked him to tell the best story that he could, like the ones that he had heard from her). The y-axis uses the skill scale for developmental levels (defined in the Appendix) as well as the steps that were assessed, which usually involved several ordered steps per level.

3.3 Skill Complexity: A Ruler for Development and Learning

Figures 1, 2, and 3 all use a developmental dimension of skill level (hierarchical complexity of action) to measure how activities vary. One of the most important discoveries of Skill Theory is this common scale or ruler for assessing learning and development. Originally, discontinuities in cognitive and emotional development provided evidence for the scale, and subsequently research on learning and ordinary performance demonstrated exactly the same scale (Dawson-Tunik, Commons, Wilson & Fischer 2005; Fischer & Bidell 2006). That is, development and learning share a fractal quality captured by the scale of skill complexity, with similar patterns of discontinuities in very different settings and time scales. The result is a powerful scientific tool, a general ruler that can be used to measure learning and cognitive development across domains and people – which provides a means for unifying a wide range of research on cognitive development, learning, and emotion (Fischer 2007).

The first clear evidence for the scale came from research on cognitive development with high contextual support. Performance at optimal level produces abrupt discontinuities in development at specific age regions, with a cluster of discontinuities marking the emergence of each new level in development. The simplest kind of discontinuity is a spurt in performance, as shown in Figure 4. Other kinds of discontinuities include reorganization to a new form of skill and gaps in Rasch (1980) scaling of items and people in tests and interviews. Performance at functional level (without support), on the other hand, shows no such systematic discontinuities in development, although less salient forms of discontinuity do occur even then, including clustering of items at each level with Rasch scaling and gaps between clusters (Dawson-Tunik et al. 2005).

In a study of reflective judgment, students between 14 and 28 years of age showed spurts in performance under optimal (high support) conditions, marking the emergence of the levels of abstract mappings, abstract systems, and principles (Kitchener, Lynch, Fischer & Wood, 1993). Under low support conditions, however, performance was lower and showed only the normative S-shaped growth curve, not a series of spurts. The scale on the y-axis is the percent of tasks passed for Level Ab3 reasoning.

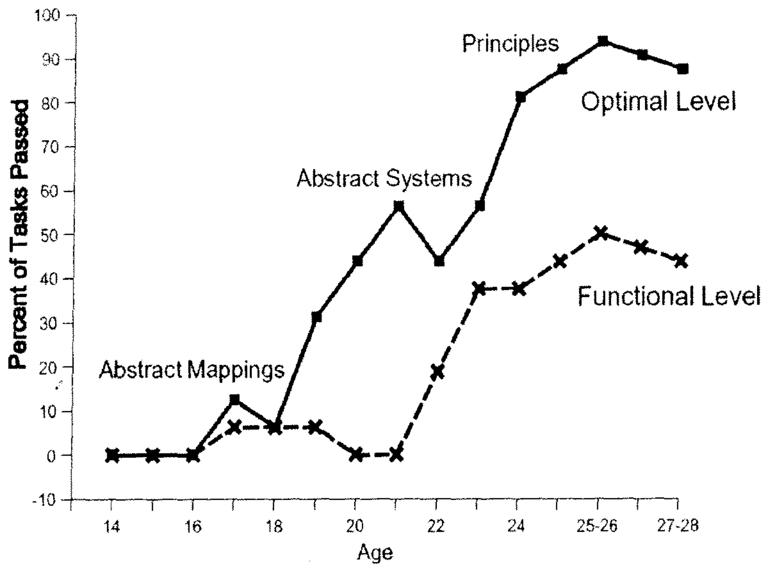

Figure 4. Spurts in development of optimal level for reflective judgment in adolescents and young adults

On the skill scale, activities vary in complexity through a series of 13 levels, including those shown in Figure 4. (Appendix 1 outlines the entire scale of levels.) Activities develop through a cycle of reorganization of behavioral and neural control systems, forming four over-arching *tiers* – reflex, sensorimotor, representational, and abstract. In the cycle the organizational patterns of one tier repeat in the next tier in a recurrence of four *levels* for each tier. A tier begins with the level of a *single* behavioral *unit*, such as in the representational tier a symbolic activity for mean action. For example, a 3-year-old acts out a story in which a boy doll named Jason is mean to another doll, hitting him and taking away his toys, thus showing a single representation for mean action. At the second level, a 5-year-old *maps* two representations together, such as having one doll (Jason) act mean to a second doll (Seth), who responds by being mean in return, *because of* Jason's meanness. Seth's mean actions are mapped with Jason's mean actions. (At the prior level of single representations, both dolls can act mean, but there is no clear relation that maps one doll's mean actions to the other's.) With the third level of the tier, representational *systems*, a child coordinates several components of each representation in a single skill, such as having two characters act both nice and mean reciprocally. For instance, a 7-year-old child makes Jason hit Seth on the shoulder while saying "Let's be friends and play", and Seth responds to both the mean and nice aspects of Jason's actions: "I would like to be your friend, but I don't play with people who hit me."

Finally, at the fourth level, *systems of systems*, which form the *new unit* for the next tier, single abstractions, a person can coordinate several systems of social interactions to form an overarching conception, such as "intention". Instead of merely taking Jason's actions at face value, a 12-year-old can compare various of Jason's actions to determine his underlying intention toward Seth, such as "You act like my friend, but you don't mean it. You just want me to help you with your homework." This fourth level of a tier represents a major neuropsychological reorganization in development and starts the next tier, serving as the new single unit in the next cycle.

The skill scale captures both long-term cognitive development (ontogenesis) and short-term learning (microdevelopment). For example, the graduate students encountering a Lego robot (wuggle) started with sensorimotor actions, which are characteristic developmentally of infants in the first two years of life. By acting on the wuggle, the students sought to understand how it worked by acting on it and observing its response to their actions. They gradually built their actions and understandings to become more complex through four levels, eventually creating complex systems of sensorimotor actions that led to single representations of concrete characteristics of the wuggle. In this way they retraced the developmental progression that infants move through between 4 and 24 months of age. (See Granott & Parziale 2002, for a thorough treatment of microdevelopment.)

With the students' creation of single representations for the wuggle, they could represent its actions and characteristics independently of their own actions on it. Then they could gradually build more complex relations among their representations of the robot, paralleling the growth in complexity of representations during childhood

(Figure 4 and Appendix 1) and understanding how different characteristics of the wuggle relate to each other. For example, if the wuggle responds to a loud sound such as a clap by reversing its direction, the students can represent the relation between the wuggle sensing the sound and its change in movement – a representational mapping.

Eventually if the students continue to work with the wuggle, they can begin to think abstractly about it, building up complex systems of representations to create skills for its abstract characteristics, such as its circuitry and programming mechanisms. These understandings start with single abstractions (intangible concepts), similar to those that pre-adolescents first construct at around 11 years of age. With continued analysis of how the wuggle functions, the students can move microdevelopmentally to higher levels of abstractions – mappings, systems, and eventually principles integrating abstract systems – as they continue to parallel ontogenesis. With abstract mappings, which first emerge around the age of 15, people formulate simple relations between abstractions, and at about age 20, they become able to organize mappings into complex systems of abstractions. The final level – abstract systems of systems, which create principles – emerges in the mid 20s, when people become able to formulate broadly integrative arguments, such as the Golden Rule in the moral domain, or descent with variation in evolutionary theory. (Note: An important point to keep in mind about the ages here and in Appendix 1 is that people as well as cultures exhibit wide variability, and the ages of emergence of levels may differ across contexts, cultures, and populations.)

Principles are the highest developmental levels to have received extensive study, although some research suggests that there may be levels beyond principles (Cook-Greuter 1999; Stewart 2002). The highest levels of abstractions (especially systems and principles) can be particularly difficult and slow to construct, even for mature adults, and many students may never reach them at all with the wuggles.

In a sense, the tiers and levels are general descriptions for capturing features of cognitive growth, but in reality human beings, especially children, are always in the midst of change, enormous change. The world around people changes every day. Remember too that a level or tier always refers to a specific skill of a person in context, never to the person in general. For instance, a person may be at one level in understanding how a computer works, but at a very different level in understanding how different materials conduct electricity. In this sense, a skill refers to a specific domain of knowledge, and is not a generalized, across-the-board level of ability. A person can gradually build a skill to be more generalized, but a skill is never totally general. Skills are always subject to variation with context, emotional state, support, and many other factors.

3.4 Processes of Transition and Construction

People construct activities in the moment, with wide variation in the nature and complexity of their skills and often with systematic growth in adaptation and complexity. Skill Theory specifies key processes in the variation and growth. We have already introduced several fundamental processes. First, situation or context exerts dominant influence in shaping activity, literally participating in the action with the person, with the consequence that development and learning move in webs with multiple strands defined by context. Second, contextual support primes activity, prompting more complex skill levels for short periods of time, with drops down to lower levels within a few minutes. Third, people routinely regress to lower levels when faced with a novel task or situation, so that they can rebuild the basic skills that they need to make adaptive skills for the situation. That is, they move to simpler levels in the face of a difficult task, which allows them to reorient skills at that lower level to create different approaches to the problem. This is one of the fundamental sources of human intelligence.

In addition, the skill scale has deep implications for the nature of processes of construction and growth, a few of which researchers have begun to investigate. The analysis of microdevelopment provides a powerful method for pinning down various processes for movement along the scale. For example, microdevelopmental research has shown the importance of co-occurrence of skills (also called shift of focus) for developmental transition: When a person can produce two distinct activities simultaneously in the same situation or shift quickly between them, he or she is close to being able to coordinate those two activities to move to a new level of skill. That is, co-occurrence of separate skills in a situation seems to be a prerequisite for combining the skills to form a more complex activity (Fischer & Bidell 2006; Goldin-Meadow, Nusbaum, Garber & Church 1993).

The discontinuities that define the scale suggest that variation and growth involve nonlinear dynamic systems with a series of attractors for each level, pulling activity toward certain regions of complexity and context and away from others. Several different scholars have created initial models of specific growth processes that may help characterize the nature of these processes (Fischer & Kennedy 1997; van der Maas & Molenaar 1992). Van Geert (1998) has created a model that generates discontinuities in both ontogenesis and microdevelopment and suggests conditions that control the occurrence of the discontinuities.

A few studies have suggested a process called *bridging*, in which people build a temporary, higher-level structure that is incomplete in its details, somewhat like a formula with unknowns in algebra. People use the temporary bridging structure to guide themselves to find lower-level activities that are relevant to the unknowns in the shell, helping them to fill in specific relevant information and components and thus build a skill that works in the situation (Granott, Fischer & Parziale 2002). With explication of some research based in Skill Theory, we can sketch how bridging and some of the other processes function in real people and situations, contributing to the variations that bring about change and growth in a given skill pathway.

4. Skill Theory Research: Processes of Knowing and Feeling

Much of the research using skill theory analyzes the processes of construction and variation in actions, thoughts, and feelings. We will focus on these studies to explicate the process nature of knowledge and emotion – the dynamic ways that they vary and the processes that allow some stability within the variation. The studies focus on how students solve problems together, how people construct feelings and concepts about themselves and others, and how learning and development generally involve active, dynamic processes of construction and change.

4.1 Wuggles

Let's return to the study that this chapter began with – the wuggles experiment. Granott (2002) devised a problem-solving task that brought pairs of students together with a little robotic creature called a wuggle. The robot responded to sound, light, or touch by making specific movements, and the challenge to the students was to build an understanding of the wuggle's behavior although they started with no knowledge or directions whatsoever about it. Coding the interactions between the partners, Granott observed the changes in activities and skill levels over a series of interactions in a session of about an hour. The continual spoken interchanges and activities allowed observation of the fluctuations in understanding, with the dyadic interactions making much of the understanding external and observable. The interactions were coded for skill levels in understanding the wuggle's behavior.

In a study of adults learning about a Lego robot, the dyad Ann and Donald worked together to understand a robot that changed movement in response to light. They build up knowledge of the robot, but it was transient, readily falling apart when the context changed. In this graph, they moved through four construction episodes in half an hour (Granott, 2002).

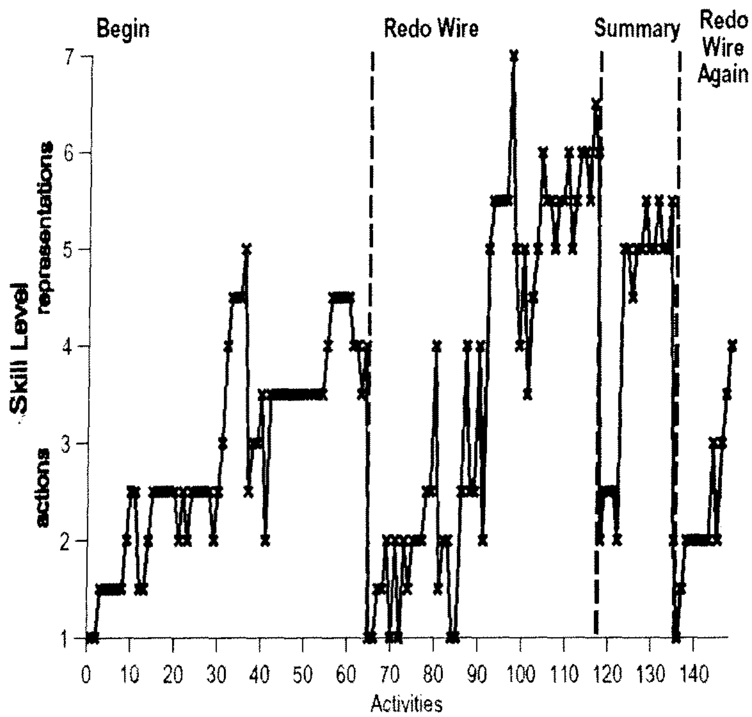

Figure 5. Repeated reconstruction of knowledge of a Lego(c) robot by the dyad Ann and Donald

The pattern of skill levels for one dyad (Ann and Donald) demonstrates dramatically that knowledge is built from repeated reconstructions, as shown in Figure 5. They clearly built up understanding from lower levels to higher levels, and the graph also shows that they repeatedly rebuilt their understanding: Several times, the levels dropped back when the situation changed in some way and the students' activity dropped in complexity. For example, at the point of the first sharp drop back to basic levels Ann and Donald had inadvertently changed the wiring of the wuggle. The next sharp drop occurred when they were asked to explain what had happened and what they had learned, a change in focus that produced lower level activities again. Their interaction shows how understanding must be reconstructed several times before it becomes relatively stable, and that returning to earlier levels is necessary for the rebuilding.

4.2 Building Bridges

As they use the microdevelopmental strategy of dropping back to build and rebuild, people make use of information in the physical world to guide their actions, and they use cognitive bridges to guide their own exploration and learning. In another microdevelopment experiment, Parziale (2002) asked fifth- and seventh-grade children to construct bridges made from marshmallows and toothpicks so that they could span an 11-inch distance between two desks. Like Granott, he used videotape and sound recordings to record activities and communication, and he used the levels of Skill Theory as a ruler for analyzing the growth patterns over time. Parziale found three prominent strategies in these children: shift of focus, distributed cognition, and appropriately enough, the process called bridging. Shift of focus and distributed cognition involved making use of specific aspects of the physical world, highlighting how knowledge is always built on action in the world and does not reside simply in the person. Bridging involved using algebra-like cognitive guidelines to direct exploration and activity and create effective activity and understanding.

Shift of focus is a literal shifting of attention from one aspect of the task to another, occurring especially when difficulties were encountered. It is an important strategy for gathering information and picking actions appropriate for a task. Dyads started out trying a number of possible actions, exploring the task's characteristics to determine an effective course of action. Most dyads used fewer shifts of focus as their activities became more consolidated: The last ten minutes of working on the bridge had roughly half the number of shifts that the first ten minutes had. At the start, with the unfamiliarity of the task, students groped to find which aspects of the task to focus on. They tried out a number of action plans before picking one or two as the way to proceed.

Even more than shift of focus, distributed cognition demonstrates how the task and context are part of people's actions and knowledge. In distributed cognition, people use environmental affordances as supports to thinking – as it were, thinking by means of the objects and events. Students building bridges with marshmallows and toothpicks relied on the physical states of the bridges to help them see what would work or not, what had to be revised, what needed to be done next. Parziale found that the constructed bridge often showed more complexity than the communicative interactions of the students. That is, the bridge itself was more complex than the level of understanding the children showed in talking about and explaining their construction of the bridge. For the students to make the knowledge explicit in their language, we hypothesize that they would have to go through the process in Figure 1, repeating the reconstruction several times. More generally, this finding shows a fundamental insight about knowledge: Human skills develop in an enmeshed way with the specific objects and events that people interact with in the world.

In the process of bridging, the children used a number of strategies to self-scaffold their progress toward higher levels of ability and understanding. Bridging is almost like having a question hang in the air, like a shell or sketch or algebraic formula with unknown variables. The hanging question is fuzzy and indistinct and full of unknowns, while people try a variety of actions and ideas to find an answer. For example, the students posed specific questions, such as how to add toothpicks in a particular way, or they observed an issue that pointed to the need for a specific action, such as noticing that the bridge seemed to be sagging close to the point of breaking. The structure of the bridging process involved using a partial understanding to help guide the assembly of information in a way that led toward a possible solution, and students used both shift of focus and distributed cognition as they pursued the bridging process and filled in the needed unknowns. Bridging seems to be a basic process for organizing action, thought, and feeling to move toward more complex and successful skills.

4.3 Emotions Organize Activity and Development.

Emotions play a fundamental role in organizing activity and development, and Skill Theory specifies how they play that shaping role (Fischer & Bidell 2006). Research on how children organize stories about positive and negative (nice and mean) social interactions illustrates one method for studying this role, as described in connection with Figures 2 and 3. One of the most basic emotional characteristics of behavior is that children, and adults as well, spontaneously evaluate all activities as positive versus negative – good for me versus bad for me. Prehension starts with good and bad as its most basic dimension. That natural split is evident in Figure 2, where nice interactions are on the left side of the web and mean ones are on the right side. Putting nice and mean together is harder (more complex) than keeping them separated. All human action begins with this fundamental fact of emotional organization.

The positive/negative split creates a basic bias in human activity – the fundamental attribution error, in which people represent themselves in mostly positive terms and treat negative characteristics and events as either unimportant or caused by other people. For example, when people are asked to diagram and evaluate themselves in their central relationships, almost everyone consistently indicates that most of their important characteristics are positive, and most of their negative characteristics are unimportant (Fischer, Wang, Kennedy & Cheng 1998; Greenwald 1980). This positive bias about self is almost universal, and it seems to be absent only when people have been horrendously abused or are deeply depressed.

This positive/negative split is only one of the many ways that emotions shape development and learning. The tools of skill theory are being used to trace pathways of emotional development and learning, both for individuals and for cultural groups (Fischer & Bidell 2006; Mascolo, Fischer & Li 2003). For example, skill analysis specifies the pathways of cognitive/affective skills that a couple builds as they are attracted to each other, fall in love, form a relationship, and then develop major difficulties with each other and break off the relationship (Fischer & Ayoub 1996). Cognition and emotion work together in shaping human activities.

Research on the microdevelopment of emotion and its role in shaping the pathways leading to healthy expressions of the self and fulfilling relationships is a prime focus of ongoing research in Skill Theory. Motivational and organizational aspects of emotion play a profound part in the construction even of phenomenal awareness and consciousness (Stewart 2006). There is much work to be done in getting to a better accounting for emotion's role in human development, and the Skill Theory framework provides a useful set of tools that honors emotion as an integral dimension with cognition in the learning and development of what Whitehead called prehension.

4.4 A Case Study of Intellectual Creativity: Darwin's Construction of the Theory of Evolution

One important result of Skill Theory's specification of how people build actions, thoughts, and emotions is explanation of how people create new knowledge. Processes such as shift of focus, bridging, and affective bias guide activity through a process of *guided groping* to find solutions to novel problems and questions. Over a period of eight years Charles Darwin constructed concepts and activities culminating in his theory of evolution, one of the most important novel theories in human history. Happily he kept daily notebooks during this period, recording his thoughts and discoveries. Drawing upon these notebooks and other biographical materials, especially Howard Gruber's (1981) important biography *Darwin on Man*, Fischer and Yan (2002) examined Darwin's thinking and problem-solving to portray how he put together his ideas and observations to create the theory of evolution.

Darwin built his theory gradually over these years, building multiple strands of understanding, which he gradually wove together to form the principle of evolution by natural selection. In constructing the principle, he groped through many ideas and observations, trying out different approaches, abandoning many of them, but often creating productive ideas and tools along the way. Darwin invented the principle repeatedly in the notebooks, only gradually realizing how the various instances of the principle all fit together to form one very general theory. This is the same process that is shown in Figure 1, in which a skill is built and rebuilt many times on the way to becoming a general scheme for knowing.

Prior to 1831, before his voyage on the Beagle from 1831 to 1836, Darwin started with single abstractions about organic versus physical aspects of the world and used them to construct abstract mappings, such as understanding the human activities of selective breeding of animals, and realizing how coral reefs relate to growth of mountains and subsidence of the ocean floor. From 1835 to 1837, his notebooks gave evidence of the development of abstract systems: for example, he came to understand that that characteristics of an animal, such as the shapes of the beaks of finches in the Galapagos, vary systematically with what the animals eat in their ecological niches. By 1837 he had arrived at the level of principles integrating abstract systems, observing that changes in both living and inorganic things took place in systematic ways and trying out various principles for explaining those systematic changes. The principles that he initially formulated were inadequate, which he realized as he worked with them; but they also created important ideas that became part of the eventual theory of evolution. For example, he tried out a principle involving monads (seeds of life that grew over time into many different species), but as working it out, he created the tool for diagraming evolutionary trees, which remains today a staple of evolutionary theory.

During the period from 1838 to 1839 the notebooks attest to Darwin's approaching his final theory several times, but not quite achieving its full realization – the pattern of building and rebuilding from Figure 1, where regression back to lower levels was necessary to consolidate and stabilize the skills at a higher level. Fischer and Yan also point out how specific components of Darwin's knowledge (for instance, his creation of a detailed model of the formation of coral reefs and the Malthusian concept of excessive breeding that creates overpopulation) seem to have been used as bridging structures that scaffolded his understanding to more sophisticated levels. He created the first full version of the theory of evolution by natural selection in 1839, but as a reminder of the importance of emotion in human action, he kept the theory quiet because of fear of the reactions that it would create in society. Only 20 years later did Darwin finally publish the theory that he had first successfully constructed in 1839, stimulated by Alfred Russell Wallace's discovery in 1858 of the broad principle of evolution.

These brief sketches of research using Skill Theory have shown how processes construction, groping, and environmental shaping produce learning and developmental pathways based in people's actions, thoughts, and feelings in their worlds. Let us now turn to some of Whitehead's ideas and look at ways of thinking about them that resonate with the findings of Skill Theory.

5. Whitehead and Skill Theory

Reading *Process and Reality* as developmental psychologists is both rewarding and challenging. On the one hand, Whitehead's effort to push through to the most essential details of the processes of reality is very much in line with our own scientific efforts: We also try to look deeper into the manifestations of behavior to discover the web of fundamental operations that flow together in the cognitive and affective growth of individuals and small groups. On the other hand, Whitehead has left us with a number of conceptual challenges: Can we really build on some of his ideas in terms that are appropriate equally to development and to process philosophy? Can we find common ground between behavioral science – which tends to seek its foundation in levels of neural organization and the chemistry of protein activity – and the meta-science of pure process and infinite connectedness? Perhaps most crucially, can we find an alliance in actual research programs that will uncover truths about how people are constituted as beings that are more interwoven with each other and the world than we had imagined before? We believe that great possibilities may lie ahead in the exploration and cross-fertilization of ideas that we are exploring.

So let us begin. We will consider two concepts that Whitehead and others have discussed at length – prehension and concrescence – to see if we can establish workable connections with aspects of Skill Theory research. Remember that we are not philosophers looking to clarify a concept in terms of Whitehead's metaphysics. Instead, we are developmental scientists looking for correspondences between the research findings related to Skill Theory and the possibility of clarifying more explicitly the details of development suggested so tantalizingly in the writings of Whitehead.

5.1 Prehension and Grasping with the Mind

Prehension has direct meaning for developmentalists because Piaget (1972, 1982), Baldwin (1906), and others have used the term to describe how children grasp things cognitively: They reach out with their minds to grasp objects, events, and people. Whitehead seems to include that meaning, but he has a more far-reaching intention in explicating its function. Whitehead seems to be asking how any interaction that can bring about change is actually facilitated. We are lucky, in a sense, in developmental psychology that we can concern ourselves with living beings and their processes – so we do not ask, for instance, how elementary particles interact.

Human and non-human animals seem to possess an inherent capacity for engaging with their environment (Panksepp 1998), so our work is about the patterns, characteristics, and outgrowths of that seeking for engagement. Growth and development require the effective coordination of capacities, so we define a capacity and then observe the way in which it engages other capacities, and what results from the interaction. Skill Theory does not usually speak in terms of the defined capacity being a self, or subject (control agent); instead it focuses on an action – which can be as simple as lifting a cup, or as complex as discovering the principles of evolution – and then specifying something about the change characteristics of the action's combination with other action capacities. Whitehead can be interpreted as saying that what is prehended is an object, and what prehends is a subject, but Skill Theory frames prehension a bit differently. The experimental work described earlier illustrates the meaning of prehension in Skill Theory.

Think of the experiment with the children building bridges out of toothpicks and marshmallows. There is really no way for a novice student to know beforehand what combination of sticks and marshmallows will prove sturdy enough to build a structure across an 11-inch span, so the children do a great deal of evaluating as they build the bridges. Fingers test sturdiness, eyes look for sagging, hands test the heft of a section; children perform many fleeting evaluations as building proceeds, settling into periods of acting on the results of an evaluation by building pieces for a time before they conduct another evaluation. Prehension can describe the taking in of data in these evaluations, but if we invoke a self/object framework for understanding, we are likely to miss the intimate connection between subject and object, person and world.

A dynamic action such as using two fingers to squeeze a triangle made of three toothpicks and three marshmallows is an action ensemble: Acting to provide information about whether the small structure will collapse with just a little squeezing, then a little more squeezing, is an exchange between subject and object that circles around all the elements at play. It is tempting to say that it is the student who prehends the characteristics of his or her triangle, but that is not a helpful way of understanding what is being developed, because the physical objects fundamentally shape the prehension. This is what Piaget and Baldwin called *groping*, feeling one's way through objects and events to see what works and how it works. Remember that the finished bridges were more complex than the developmental levels that the children showed in discourse. The objects in some sense carried the understanding. So if there is more "development" in the bridge than in the expressed thinking structures of the students building it, is it misleading to claim that the subject is the center of all action?

Following more the spirit than the letter of Whitehead's ideas, we see prehension as a dynamic process that cycles through entities rather than being drawn into a subject. This is just the kind of question that will be useful in clarifying conceptions of growth. When Whitehead says of prehensions that "they feel what is *there* and transform it into what is *here*" he is trying to account for how something is added to a system, which can then use the addition for change. But for Skill Theory, a large part of the way a skill is conceptualized involves close adaptation between the "there" and the here, the capacity: A skill is an enactive dynamic in which there and here are already committed to each other. The world and the person are fitted to each other because people have evolved to use the world intimately and thoroughly. Human embodiment starts in potential integration with a fully available world.

5.2 Concrescence and Groping

The integration of prehensions starts as potential. People have to construct the integration from the potential by acting in the world, combining and differentiating skills to create a new prehension that is adapted to the particulars of a context. This process of combination and differentiation relates to Whitehead's concept of concrescence, which is in essence a growing together of prehensions. In concrescence, according to Skill Theory, people grope to combine skills and skill components in order to grow more complex and differentiated skills. Whitehead's emphasis was on the phases of concrescence and how they might clarify a unification in a moment of experience. Skill Theory focuses more on growth and less on experience in the phenomenal sense, but experimental work on learning can help ground what concrescence means when applied to human action and development.

First, think back to the experiment with the robotic wuggles. Each time the situation changed unexpectedly, the skill level of the students' understanding plummeted back to lower levels. The students had to build new paths of understanding, and they went back down as far as they had to in order to find something that they could confidently do with the wuggle so that the new structure for understanding could be based on a solid foundation. How does that regression to low level skills work? It is rapid, and much of it is unconscious or vaguely on the edges of conscious, as implied by the word "groping" for the right skill. It involves finding a low-level familiar skill that can be used to act with the wuggle, or else groping to create a new low level skill for that purpose.

There is a parallel in Darwin's development of evolutionary theory. Remember that according to his notebooks he built up various versions of his theory a number of times, but required months and years of elaboration and repetition before creating his own full understanding. How should we think about the fact that Darwin sat before his own notebook, where many specifics of the theory were written down, but could not at that time understand it in the full, generalized sense that he eventually created. Gradually he groped toward building his theory. There were many instances when he had intense "aha" experiences of discovery, some of which led to useful insights, such as the role of natural selection and others of which led to failed ideas, such as monads that generate life. But he groped his way through many such experiences before he succeeded in constructing the long-term generalized principle of evolution by natural selection. It takes a long time to build deep understanding.

In the youngsters who built bridges, the process called shift of focus or co-occurrence illustrates how objects and events in context shape the students' groping toward concrescence. Children can have short attention spans, but in the bridge study shift of focus appeared to be due to more than that. It happened typically when students lost their productive focus on a task; they sensed that the activity they were trying was not going to work and that some other aspect of the situation might be more productive, as if it called for their attention. Shifts of focus are about changes in approach and focusing on different aspects of a situation, not at all about giving up on the overall project. The goal of completion of the task seems to provide an emotional charge that propels a child toward groping and exploration of possibilities, and slight fluctuations in the charge recruit shifts in deployment of skills to another thread in the web of exploration, evoked by some aspect of the situation. Although these states seem to involve feeling and energy shifts, in a deeper sense they appear central to orchestrating actions and combinations of actions (concrescence). So we have suggested here that certain feelings interacting with context may be essential in microdevelopmental processes. Are these seemingly crucial felt sensibilities tied in to Whitehead's moments of experience? Do they contribute to the development of higher skills involving new organizations of activity? Do they suggest a potentially fruitful point of contact between the two theories?

Whitehead says that the end of the processes of concrescence produces satisfaction as the moment of experience they engendered dies away to become an object for future concrescence. In a similar fashion, Skill Theory says that the melding and rehearsal of skills gradually results in stable structures that are then available for more automatic use. While Whitehead has much more to say about how present moments of experience are sustained, Skill Theory emphasizes and investigates explicit ways in which emotion and cognition work together in learning and development.

Maybe this is fertile ground for dialog between the two approaches. Can we look for methods to explore the development of phenomenal experience and consciousness, guided by the conceptual structures Whitehead proposed for finding them? Whitehead explored how things touch and shape each other in ways that few other philosophers have had the courage to think through so completely. Skill Theory is one of the most successful approaches to development, in part because it captures both cognition and emotion in the dynamic interplay of growth. We hope that by some combining of philosophies and research strategies in the coming years, the two approaches together can tell a story about how people grow up in a universe where connections to each other, to animals and to the planet, even to the stars, are real and are open to exploration and growth.

In our final section, we will look at some of the historical ties that link developmental psychology with Whitehead's philosophy, and we will present a view of the human being in Whitehead's words.

6. Historical Backdrop: Whitehead, Pragmatism, and Piaget

Connections between Piaget and Whitehead have not gone unnoticed (Fetz 1988; Flyn 1995; Riffert 1999, 2003), but similar connections between Whitehead and the current state of neo-Piagetian research have yet to be explored. Every process has progenitors. The two "modes of thought" brought together here share important ancestors. Piaget and Whitehead owe a lot to the American Pragmatists, who exemplified the reconstructions in philosophy and psychology following in the wake of Darwin. The Pragmatists made clear that both philosophy and psychology should be couched in evolutionary and processual terms.

In the Preface to his remarkable *Principles of Psychology*, William James (1890/1950) was quick to point out the line where psychology ends and metaphysics begins. James's concern with demarcating these disciplines is warranted, given that the history of "psychology" prior to the publication of *Principles* reads like a primer on panpsychist metaphysics. For example, among the names covered in any history of psychology (e.g., Boring 1929) are Lotze and Fechner. Both of these founders of scientific psychology had explicitly developed and published panpsychist metaphysical views. Of course, one could add Spinoza, Leibniz, and Kant to the history of psychology (see Baldwin 1913). These more distant philosophical antecedents to scientific psychology were also panpsychists (Skrbina 2005). In contrast, James wanted a scientific psychology. He pledged his allegiance to the naturalism spawned by Darwin by looking to the physiology and function of the mind in an evolutionary context.

Whitehead learned from James (Weber 2002), and from the Pragmatists in general. In the opening pages of *Process and Reality* he declares his debt to Dewey and James, admitting his preoccupations with rescuing their thought from its associations with anti-intellectualism. Elsewhere, he characterized the innovations of the Pragmatists as comparable to those of ancient Greece, labeling James as Plato and Peirce as Aristotle (Hartshorne 1972). So it is no mistake when careful scholars (Griffin 1992; Rescher 1996) group Whitehead with the Pragmatists.

The admiration was, in some respects, mutual. The Pragmatists would have Whitehead as one of their own. Indeed, Dewey wrote three pieces about Whitehead's philosophy (Dewey 1926, 1937, 1941). In each piece he applauds the critique of the 'fallacy of misplaced concreteness'. Dewey suggests that Whitehead's philosophy is amenable to his own, citing a shared emphasis on embodied experience, processes of becoming, and the non-reductionist naturalization of humanity's place in nature.

More importantly, Dewey places stress on the insights Whitehead offered regarding the nature of philosophical method. He commends Whitehead's contention that philosophy ought to out-generalize the sciences while still staying within the purview of what is suggested by their evidence. Although the overwhelming tone is positive, Dewey wishes that Whitehead would more carefully circumscribe his speculations, suspecting that, in the end, the mathematician in Whitehead beats out the scientist, and the rationalist the empiricist. Still, Dewey sees the broad contours of their approaches as more or less aligned.

Interestingly for our work, Dewey ends his review of *Science and the Modern World* by suggesting that educational psychology has the most to gain from a careful consideration and application of Whitehead's views. He reflects that a "psychology emancipated to deal with organisms as genuine organisms would be a very different thing in its [...] educational and social bearing" (Dewey 1926, 361). This echoes Whitehead's own sentiments on the need to understand educating minds as analogous to providing environments for the flourishing of organisms (Whitehead, 1929/1967).

Our work is strongly connected to that of Jean Piaget, who like us was strongly shaped by the pragmatists. Despite the profound influence of Bergson on his early development, Piaget (1972) was more an epistemologist than a metaphysician. He inherited almost the same history of psychology as James, which reads like a compendium of epistemologies. Like James, Piaget was at pains to clarify his project in relation to philosophy. Like Whitehead, he came to see that philosophy and science should be collaborative enterprises (Piaget 1970, 1971).

Piaget's reflections on philosophy, like his more famous notions about cognitive development, can be traced back to the fertile intellectual environment that gave birth to Pragmatism. At least one neo-Piagetian scholar, Lawrence Kohlberg (1982), was careful to point this out, especially Piaget's use of J.M. Baldwin's work as foundational. Kohlberg traced a line that went from his own work through Piaget's influential book *The Moral Development of the Child* and straight to Dewey, and then back to Baldwin. Piaget (1982) himself traced a similar line of influence, confessing that his project emerged from the transformations reverberating though psychology and philosophy in the wake of Darwin and basing much of his work explicitly on Baldwin's ideas.

Following Piaget's lead, decades of research into the dynamics of human development have revealed a rich and suggestive body of findings. These have demonstrated the existence of developmental levels (but not strict stages), the non-synchronic development of various skills across those levels, marked differences between functional and optimal levels of performance, and inextricable links between the development of cognition and the development of emotion. Cognitive development is now best characterized in terms of dynamic systems propelled by iterative self-organizations calibrated in relation to some context or environment (Fischer & Bidell 2006;

Van Geert 1994). It is also best characterized as bathed in increasingly complex states of feeling, emotionality, valuation, and purpose (Fischer et al. 1990; Fischer et al. 1998; Greenwald 1980; Mascolo et al. 2003; Panksepp 1998; Stewart 2006; Sullivan 1953).

Likewise, Whitehead's metaphysics has grown increasingly relevant. It has been refined by application to a variety of philosophical areas, including the philosophy of theology (Cobb & Griffin 1976), mind (Griffin 1998), science and religion (Griffin 2001), physics (Eastman & Keeton 2004), and education (Allan 2004) – to name a few.

7. Whitehead's View of Human Beings

Human beings are, of course, compound individuals. We are tremendously complicated organisms. Each of us subsumes a vast nexus of low-level societies of occasions. These are coordinated by a central nervous system that is itself a cooperative network of occasions manifesting and governed by a personality. What we experience as consciousness is but the tip of an iceberg (to use Freud's metaphor). Every cell in our body communicates its experience to our nervous system to some degree. Our personalities attempt to ride atop this current of feeling and give direction and purpose to the complexity and richness of our experiences.

It's worth quoting Whitehead at length here:

> All the life in the body is the life of the individual cells. There are thus millions upon millions of centers of life in each animal body. So what needs to be explained is [...] the unifying control, by reason of which we not only have unified behavior, which can be observed by others, but also consciousness of a unified experience. [...] The living body is a coordination of high-grade actual occasions; but in a living body of a low type the occasions are much nearer to a democracy. In a living body of a high type there are grades of occasions so coordinated by their paths of inheritance through the body, that a peculiar richness of inheritance is enjoyed by various occasions in some parts of the body. Finally, the brain is coordinated so that a peculiar richness is inherited now by this and

> now by that part; and thus there is produced a presiding personality at that moment in the body. Owing to the delicate organization of the body, there is a returned influence, an inheritance of character derived from the presiding occasion and modifying the subsequent occasion through the rest of the body. (Whitehead, (1929/1978, 108f)

Skill Theory explains how the modification of this organization happens gradually in learning and development.

8. Summary and Conclusion: Dynamics of Process and Skill

Skill Theory explains how complex behaviors arise from the actions of brain, body, and world, being created dynamically in each instance by the process of coordination, including combination and differentiation. People construct their own development and learning in elemental steps that can be observed and studied, revealing laws that explain how we act in the complex ways that we do. Skill Theory provides a set of tools, both conceptual and material, to empirically determine the story of how people build their specific activities, using simpler structures to construct more complex ones – not just in the young but throughout the life course, not just over months and years but in the moment. People build skill and understanding along specific developmental pathways that grow from activities in the world, such as manipulating a gadget, building a model of a bridge from marshmallows and toothpicks, or debating about the relation between Whitehead's concepts and those of Skill Theory. Each person acts in a variable range along his or her pathways, not with a fixed skill or understanding.

These developmental processes appear to resonate with Whitehead's descriptions of processes underlying the structure of reality. The remarkable closeness of the process functions in Skill Theory and Whitehead's analysis can help open a constructive dialog between the fields of education, psychology, philosophy, and biology that may lead to fuller, deeper explanations of human behavior and its connections with other levels of existence analyzed by physics and chemistry.

Two of Whitehead's concepts resonate particularly clearly with Skill Theory: prehension and concrescence. Prehension in Skill Theory is a dynamic process by which a person grasps and coordinates the components of an activity, cycling through entities rather than being drawn into a subject. Concrescence is in essence a growing together of various prehensions, which Skill Theory analyzes into processes of combination and differentiation of skills to create new entities (activity patterns or higher level skills) that are more complex or adapted to a particular situation.

At the very least, this dialog between cognitive-developmental science and process philosophy can lead to new ways of thinking about how it is that people participate in their world and with each other, and what possibilities may lie ahead for people to grow, both as individuals and as a species.

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Appendix:

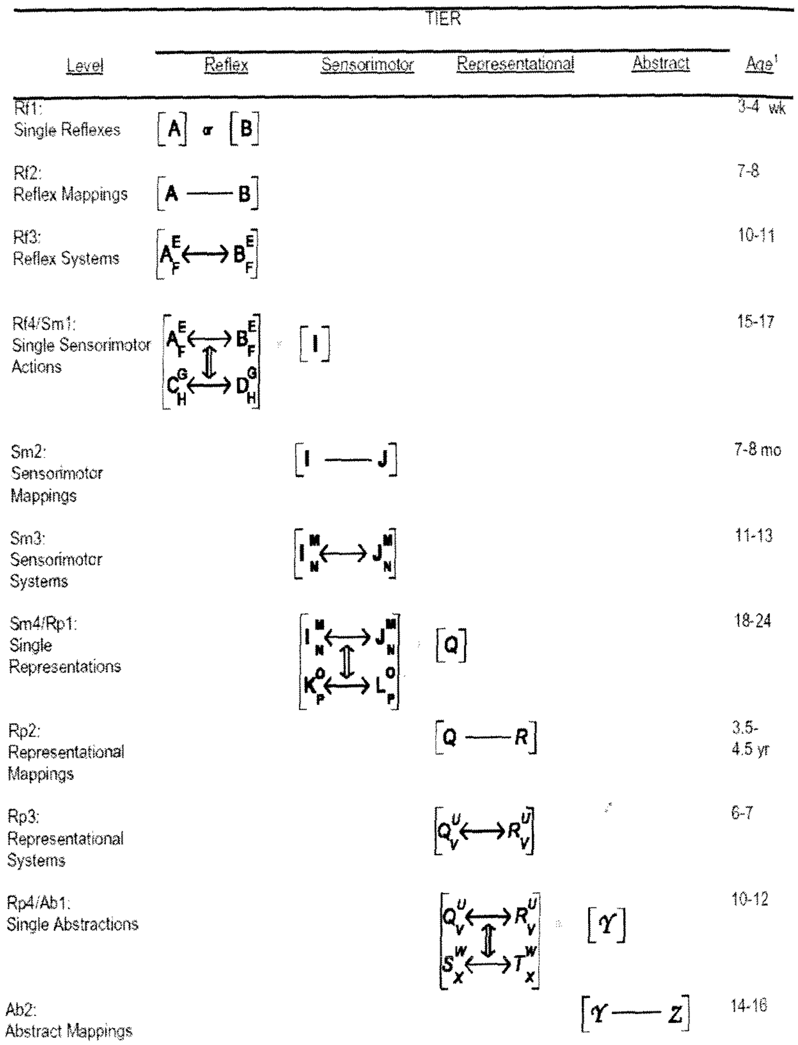

Figure 6. Levels of Development of Psychological and Cortical Activity
[1]Ages are modal for emergence of a level according to research with middle-class children and may differ across social groups.

Caption: In skill structures, each letter specifies a skill component. Each large letter indicates a main component (set), while each subscript or superscript denotes a subset of the main component. Plain letters indicate components that are reflexes, in the sense of innate action-components. Bold letters indicate sensorimotor actions; italic letters representations; and script letters abstractions. Lines connecting sets mark relations forming a mapping, single-line arrows mark relations forming a system, and double-line arrows mark relations forming a system of systems. (Fischer & Bidell, 2006)